GLOBETROTTER: AN AIRBAG HOPPER FOR LUNAR SURFACE AND PIT/CAVE EXPLORATION. Pascal Lee[1,2,3], J. Ed Riedel[4], Laura L. Jones-Wilson[4], Erich J. Brandeau[4], Clara O'Farrell[4], John C. Gallon[4], and Ryan S. Park[4]. [1]SETI Institute, [2]Mars Institute, [3]NASA Ames Research Center, [4]NASA Jet Propulsion Laboratory.

Summary: GlobeTrotter is a concept for a universal airbag-based robotic hopper for rapid, low-cost, and robust exploration of the surface and subsurface (pits, caves) of the Moon, Mars, Phobos, Deimos, and other small bodies. This paper presents an application of GlobeTrotter to lunar exploration, in particular as a versatile scouting capability in support of humans returning to the Moon.

Introduction: To date, less than 0.002% of the 38 million km^2 of the Moon's area has been explored from the surface. Vast tracks of lunar highlands and maria, including discrete regions and features such as impact basins and craters, volcanic centers, lunar rilles, lunar pits and caves, and the permanently shadowed regions (PSR) of the lunar poles, remain unexplored from the surface. The maria are topographically benign at large scales (hm to km) but can present significant roughness at small scales (m to dm), *e.g.* large boulder fields [1]. The highlands present slopes at hm scales that commonly exceed 15°-20° and often reach angle of repose (32°-35°) [2]. Their surface roughness at small scales replicates that at larger scales [1]. The youngest large impact craters on the Moon present even steeper slopes and rougher terrain [3]. The lunar poles, where the H_2O ice-rich PSRs are located and where NASA aims to land astronauts by 2024 (South Pole) are in rough and steep-sloped highland terrain. Robust *in-situ* robotic precursors capable of rapidly scouting out large areas of the lunar surface, including the cold, dark, deep interiors of the PSRs, and requiring little development time or cost, are needed. Meanwhile, lunar pits and caves, which will also attract human explorers for science and might offer shelter and potential resources too, present novel exploration challenges [4]. Conventional concepts such as robotic rovers, walkers, danglers and landers all face the major risk of interacting with poorly known, likely rough terrain, as well as limited dwell times in cold, dark, and comms-denied caves. Drones have been proposed [4], but alternative options should also be considered.

New Approach: GlobeTrotter is an airbag-based robotic vehicle that could robustly and quickly explore vast areas of the Moon via "leaps and bounds", tolerant to terrain roughness and using slopes to its advantage **(Fig.1)**. The approach emphasizes aerial coverage (range) and access to extreme terrain (trafficability) while offering diverse science focus options (mission versatility). GlobeTrotter could, at higher latitudes, keep pace with the shifting lunar terminator and investigate terminator processes such as charged dust transport. GlobeTrotter could also drop into pits/caves, hop around inside, and fly out of them again **(Fig. 1).**

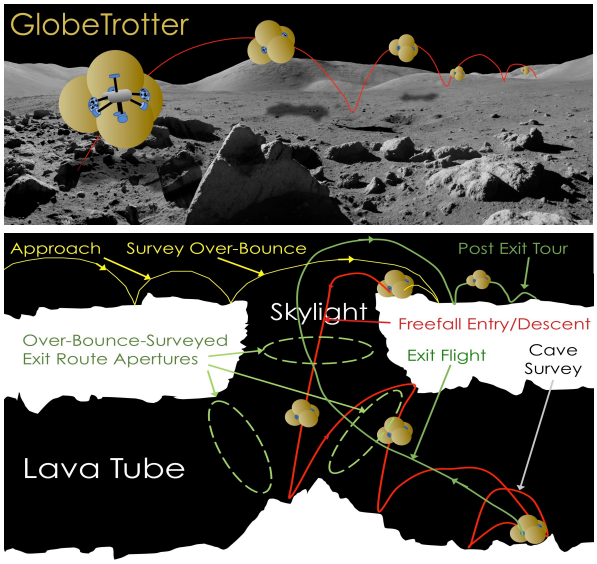

Figure 1. GlobeTrotter on the Moon. Top: Surface exploration. **Bottom:** Lava tube exploration.

Payload: GlobeTrotter's payload, while limited in mass, volume and power, would enable missions of compelling scientific merit. Core instruments include:
- *Color Imaging System (CIS),* a multidirectional array of small RGB color cameras for science (geology, atmosphere), H_2O-ice prospecting, navigation, and hazard avoidance, with LEDs to image shadowed areas.
- *Neutron Detector (ND)* to measure regolith hydrogen abundances at spatial resolutions of 1-10 m for science (geology) and resource prospecting (OH / H_2O ice).
- *Accelerometers* to reconstruct attitude, position, and speed *vs* time, and map slope profiles in the PSRs.

Depending on mission goals, other low mass/volume/power payloads may be considered.

Airbags: GlobeTrotter's airbag system may take one of several forms: a single expandable shell, a set of adjoining airbags, or an open airbag lattice. GlobeTrotter builds on NASA's Mars Pathfinder and Mars Exploration Rover landing system heritage, but with a larger volume to mass ratio and lighter airbag materials robust against rapid leakage, punctures, and rips.

Power: GlobeTrotter is electrically solar powered.

Propulsion: GlobeTrotter uses gas thrusters for long-range leaps, and selective airbag "cinch & release" cycles for short-range displacements. It may also be allowed to roll freely down gravity gradients.

Communications: Direct and/or indirect to Earth.

References: [1] Rosenburg, M. et al. (2011). *JGR Planets* 116. [2] Krevalsky, M. et al. (2013). *Icarus* 226, 52-66; [3] Kreslavsky, M. & J. Head (2016) *Icarus* 273. [4] Lee, P. *et al*. (2019) *50th LPSC*, #3118.